AN EXPLORATORY STUDY: THE DEVELOPMENT OF PRIMARY VERBAL MEMORY CAPACITY IN MALE CHILDREN

By

GARY STEVEN SARVER

A DISSERTATION PRESENTED TO THE GRADUATE
COUNCIL OF THE UNIVERSITY OF FLORIDA IN PARTIAL
FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

1973

Copyright

by

Gary Steven Sarver

1973

DEDICATION

To Ann, Andrea, Sam, Judy, George,
Harry, and Tigger

ACKNOWLEDGMENTS

I would like to thank Dr. Wiley Rasbury for allowing me to take credit when all was well, and allowing me to blame him when all wasn't so well. I would like to thank Dr. Paul Satz for his continued valuable guidance, assistance, and support throughout my graduate career; Dr. Franz Epting for providing patient understanding to my frenzied ideas, and a role model of a professional researcher; Dr. Jacquelin Goldman for my clinical super-ego; Dr. Robert Isaacson and Dr. Frederick King for directing a clinician through their neuroscience arena; and the Department of Communication Sciences. I would like to thank my supervisory committee for their considerable investment in me,

I would like to thank my parents who were, and continue to be, there when I need them. I hope to return the commitment.

I would like to thank Mr. Wood, his teachers, and their children for their spirited participation.

Finally, I would like to thank Dr. Ken Heilman who once said: "Hey Gary, I want you to see something very interesting that happens to memory function after head trauma." Enough said.

I would like to thank my daughter, Andrea, for taking me away from all this when I most needed to be taken away from all this. I intend to thank my colleague, editor, therapist, nurse, special worker, economist, fellow student, comedian, admirer, lover, zoo-keeper,

business partner, co-conspirator, mistress, secretary, housekeeper, assistant mechanic, psychologist, and wife named Ann...as soon as she wakes up.

TABLE OF CONTENTS

Page

ACKNOWLEDGMENTS iv

LIST OF FIGURES vii

ABSTRACT viii

INTRODUCTION 1

METHOD 11

PROCEDURE 12

RESULTS 14

DISCUSSION 29

APPENDIX A: Taped Instructions Given to Subjects 37

APPENDIX B: Digit Presentations for the Four Treatment Conditions 38

BIBLIOGRAPHY 40

BIOGRAPHICAL SKETCH 44

LIST OF FIGURES

Figure		Page
1	Mean number of ordered digits correctly recalled as a function of grade.	15
2	Mean number of ordered digits correctly recalled as a function of delay.	17
3	Mean number of ordered digits correctly recalled by grade for each treatment.	18
4	Mean number of ordered digits correctly recalled by treatments for each grade.	20
5	Mean free/ordered differences as a function of delay.	23
6	Mean free/ordered differences plotted for each grade across treatments.	24
7	Serial position curve for 8 digits at the 100 millisecond ordered condition for each grade.	25
8	Serial position curve for 8 digits at the 1600 millisecond ordered condition for each grade.	27
9	Serial position curve for 8 digits at the 1600 millisecond free condition for each grade.	28

Abstract of Dissertation Presented to the
Graduate Council of the University of Florida in Partial
Fulfillment of the Requirements for the Degree of Doctor of Philosophy

AN EXPLORATORY STUDY: THE DEVELOPMENT OF PRIMARY VERBAL MEMORY CAPACITY IN MALE CHILDREN

By

Gary Steven Sarver

August, 1973

Chairman: Paul Satz, Ph.D.
Co-Chairman: Wiley Rasbury, Ph.D.
Major Department: Psychology

This study investigated the development of primary verbal memory capacity in male children.

Fifty-six male school children, fourteen each from grades K, 2, 4, and 6, recalled serial digits which had four variations of inter-digit delay: 100, 600, 1100, and 1600 milliseconds.

Age, Delay, and the interaction of AGE X Delay were all significantly related to the number of digits correctly recalled.

While the literature suggests that age-related increases in digit recall may be a function of increasingly sophisticated mediational strategies there was no direct evidence in this study to suggest that mediational strategies were, in fact, operating. There was some indirect evidence available from serial position curves to support such a hypothesis. Extension of the delay conditions used in this study may provide additional supplemental evidence to support the hypothesis of the use of mediational strategies in serial digit recall.

INTRODUCTION

Purpose

The present study was designed to provide information regarding the development of primary and secondary verbal sequential memory in male children. A modification of the now classic "Digit Span" task utilized in the Binet and Wechsler intelligence scales provided the basic memory task employed in the present study. The specific design required children to recall serial strings of digits at various rates of presentation. In essence, it was presumed that effective recall would be a function of general maturation and/or the development of cognitive strategies.

Verbal Memory

The concept of "verbal memory" has effectively eluded adequate definition; however, it is generally defined as an ongoing process composed of acquisition, storage, and retrieval functions which utilize language. Traditionally, it has been difficult to isolate each function. Thus, there is little empirical evidence regarding the relative contribution of each function to verbal memory. Inasmuch as the usual empirical indicator of an operative memory process is recall, the investigation of acquisition and storage functions must be inferred from recall performance, a confounding factor in itself. In addition to these methodological problems, and in part because of them, there are pertinent theoretical disagreements concerning the operation of the memory process.

Differentiation of the Memory Process

An ongoing debate continues as to the existence, nature, and function of short-term and long-term memory. McGaugh (1970) proposed four distinct interrelationships that short- and long-term memory might share: (1) short- and long-term memory may simply represent opposite poles on the same continuum, (2) short- and long-term memory may be two mutually exclusive processes, (3) short-term memory may influence or affect long-term memory, but be totally unnecessary for long-term memory to exist, or (4) short- and long-term memory may be separate processes, but short-term memory might be a necessary process in the sequence of events leading to long-term memory.

Support for the continuum position comes from research demonstrating that short-term and long-term memory are affected by the same experimental parameters. For example, it has been shown that: (1) repetition (Norman, 1969) and rehearsal (Melton, 1970) enhance both short- and long-term memory, and (2) retroactive and proactive interferences operate in both processes. However, the research has not clearly supported the existence of proactive interference in short-term memory (Melton, 1970).

Other data imply that the two processes are independent. McGaugh (1970) reported that certain types of drugs and electroconvulsive shock can have differential effects on memory. Some drugs facilitate short-term memory (strychnine, nicotine, picrotoxin, pentylenetetrazol), while other drugs disrupt long-term memory (puromycin, acetoxycycloheximide). Similarly, electroconvulsive shock disrupts short-term memory, but not long-term memory. While these observations are based upon animal research there is some evidence to support similar differential effects in humans.

For example, some drugs (sodium amytal) have a deleterious effect on short-term memory, but not long-term memory (Milner, 1970). Furthermore, electroconvulsive shock has a disruptive effect on short-term memory, but not long-term memory in humans (Barbizet, 1970). Milner (1970) has also demonstrated that the two processes might be separate in patients with bilateral hippocampectomies. She observed that information could only be retained if it were kept in immediate consciousness, and that it could not be transferred to a permanent memory store. However, as Isaacson (1971) notes, these observations were made on individuals suffering from temporal lobe epilepsy and may not be generalizable to the population as a whole.

The bulk of the literature suggests that neither the continuum position, nor the independent-processes position is clearly tenable. In view of these findings, the more recent research has focused on the notion that long-term memory does not require short-term memory as an antecedent condition, but nevertheless is subject to its influence, or, that short-term memory must be a necessary process which precedes long-term memory.

Waugh and Norman (1965) have maintained a two-process distinction in their theory of memory operation, but have realigned some traditional concepts. They have proposed an immediate memory process which precedes and influences a long-term memory process. Waugh and Norman (1965) suggest that all incoming information registers in "primary memory." Primary memory is qualitatively different from secondary memory on several parameters. First, primary memory is a faithful reproduction of the immediate past events, whereas short-term memory is not. That is, short-term memory is subject to errors of omission and commission. Secondly, the information in primary memory has never left consciousness, whereas the information from secondary memory is retrieved from the past. Conversely, the traditional first stage of memory, short-term memory, is perceived as being part of the secondary memory process along with long-term memory.

Presumably, information from primary memory passes into secondary memory by way of an active cognitive process such as repetition of the material, or a strategy which facilitates handling of the material. Empirically, it has been observed that subjects are able to retain items in primary memory if there are no distracting stimuli, or if the number of stimuli do not exceed the system's capacity to respond to them (Waugh and Norman, 1965; Waugh, 1970; Norman, 1969; Broadbent, 1958; Milner, 1970; Belmont and Butterfield, 1969).

The theoretical position of Waugh and Norman (1965) will be adopted herein as a model from which to study primary verbal memory development in male children. Again, it appears that there is a long-term memory process, designated secondary memory, which is composed of the traditional short- and long-term memory processes. In addition, an immediate memory process, designated primary memory, is presumed to be a necessary antecedent event for the occurrence of secondary memory.

Secondary Memory

In their review of the literature Belmont and Butterfield (1969) concluded that there is no relationship between the forgetting rate of secondary memory and either chronological or mental age. That is, while there were differences in the absolute amount of material recalled, there were no observed differences in the rate at which forgetting occurred. Thus, while the older and more intelligent subjects learned more initially and remembered more on recall than the younger and intellectually dull subjects, the rate at which both groups forgot the material was parallel. Therefore, it appears that recall functions are not as significant in the observed differences as are the acquisition and/or storage functions.

In an attempt to understand the differences in the absolute amount of material recalled, attention is now focused on the acquisition/storage functions of secondary memory. Further, since storage functions are so methodologically difficult to isolate, the focus is essentially restricted to the review of the literature dealing with the acquisition function of secondary memory.

The Acquisition Function of Secondary Memory as Seen in Mediational Strategies

In accordance with Waugh and Norman (1965), a mediational strategy is presumably employed to move information from primary to secondary memory in the service of the acquisition function of the secondary memory process. Interruption of this cognitive process prevents the movement, and hence the material cannot be recalled. Strategies typically consist of individually applied methods of grouping or rehearsing which can be reliably observed (Belmont and Butterfield, 1969).

The developmental literature consistently supports the hypothesis that as children mature they develop the ability to use mediational strategies appropriately and effectively in dealing with memory tasks (Flavell, 1971; Flavell, Friedrichs, and Hoyt, 1970; Hagen, 1971; Neimark, Slotman, and Ulricht, 1971; Belmont and Butterfield, 1969). However, while there is general agreement concerning the progression of mediational development there are two separate vantage points from which this same progression is viewed. Thus, there are those who feel that young children do not have the verbal mediators.in their repertoires (Flavell, 1970; Goulet, 1968; Rossi, 1964; Daehler et al., 1969; Cole, Frankel and Sharp, 1971; Corsini et al., 1968; Moely et al., 1969; Belmont and Butterfield, 1969), and others who believe that young children possess the mediators, but do not utilize them (Kendler, 1963; Luria, 1961; Reese, 1962). Further, there is a lack of consensus concerning the onset of significant transition points in the development of mediational strategies. Smirnov and Zinchenko (1969), and Appel et al. (in press), observed that three- to four-year-old children initially displayed no purposeful remembering behavior. Then, at approximately four-and-a-half years old they display purposeful remembering behavior, but lack the mediational skills which would facilitate memorization. Finally, at approximately six years of age, they reach a point where they display purposeful remembering behavior and have the requisite mediational skills which allow them to engage in effective verbal strategies. Further, Smirnov and Zinchenko (1969) observed a substantial increase in the utilization of mediational strategies between the ages of nine and eleven years. While Smirnov and Zinchenko (1969) observed the greatest strides as occurring between four and five, and nine and eleven years of age, others have found the greatest strides occurring between six and eight years of age (Rossi, 1964). However, this latter study involved specific classificatory behaviors rather than general memory skills, and may not be as generalizable as Rossi presumed.

In any event, the evidence suggests that as children mature they become more efficient at memorization due to the increasing use of verbal mediation.

In addition to the increased effective utilization of verbal mediators with age, the literature suggests that retardates use inefficient types of mediational strategies, if they use them at all. Ellis (1963) first proposed that retention in retardates would be inferior to that of normals. He subsequently found (Ellis, 1969) that retardates could recall the most recently presented items in a serial list as well as normals could (recency effect); however, the normals were superior in their ability to recall items from the beginning and middle of the lists. Similar results were obtained by Belmont and Butterfield (1969).

Belmont and Butterfield (1969) demonstrated that retarded subjects did not show any observable pattern of delay during the learning of a serial position task, whereas normals did. Importantly, delay was significantly associated with increased recall, and patterns of delay changed with instructions to alter strategy. Delay thus seems not only to be a reliable indicator of strategy, but from the theoretical vantage point of Waugh and Norman (1965) provides the requisite time for the occurrence of the cognitive operations which facilitate the movement of material from primary to secondary memory.

In an attempt to explain the similar recency performance for retardates and normals, Belmont and Butterfield (1969) suggested that both performances involved "passive exposure memory," or perhaps primary memory, which was presumably equal for both groups. However, the authors felt that those items in the beginning and middle of the lists had passed into secondary memory during the periods of delay. Indeed, delay was found to be reliably associated with increased recall, and the normals delayed significantly longer than the retardates who uniformly failed to delay at any point in the learning of the serial lists. Thus, delay has been reliably related to increased recall.

In summary, the acquisition function of secondary memory appears to be positively related to the use of a strategy or some general cognitive operation. Further, the efficient use of such mechanisms seems to increase with both chronological and mental age.

Primary Memory Process

While the relationship of secondary memory to mental and chronological age has been thoroughly investigated there has been little systematic investigation of primary memory as it relates to development.

There is sound evidence to support the notion that primary memory spans a fixed number of events (Waugh, 1970; Norman, 1969; Waugh and Norman, 1969; Broadbent, 1958; Miller, 1956; Nevelsky, 1970). For example, Miller (1956) determined that the capacity of immediate memory was seven-plus-or-minus-two "chunks" of information. However, each chunk can contain many "bits" of information. Thus, while there is a limit to the number of discrete new stimuli which can be incorporated within some finite time, this potential informational bottleneck is overcome by grouping many bits of information into a few chunks. This is precisely the function that mediational strategies apparently serve; namely, the grouping or organizing of material into manageable chunks.

Interestingly, Heilman (1972) has noted in cases of dominant left hemisphere trauma, that immediate verbal memory is reduced to three-plus-

or-minus-one. However, if the individual's higher cortical functioning remains relatively intact new information can be learned if presented as three or four bits of information over two trials, rather than as seven bits in one trial.

In both instances (Miller, 1956; Heilman, 1972) it remains unclear as to whether primary or secondary memory is what was being tapped. In each case the interstimulus interval (digits, letters, numbers, decimals, objects) was at least one second; presumably a delay which may still allow time for a strategy to be utilized. Thus, there is as yet no clear picture of primary verbal memory or its development.

Summary

In view of the reported literature the following observations can be made. It is apparent that the relationship of secondary memory to chronological and mental age has been extensively investigated. Research indicates that the mediational strategies employed in secondary memory are significantly related to the amount recalled. Further, the efficient use of mediational strategies increases with chronological and mental age.

Secondly, there is as yet no clear picture of primary verbal memory development or its capacity. While Wechsler (1949) has observed that the capacity to recall digits increases with age and that normals recall more than retardates, the method of digit presentation is subject to the same criticism applied to Miller's (1956) work; namely, the rate of digit presentation provides an uncontrolled period of delay during which a mediational strategy might be employed.

The Present Study

The present study was designed to investigate the development of primary verbal memory capacity in male elementary school children. In accordance with the literature demonstrating secondary memory involvement during periods of delay, four distinct inter-digit intervals were utilized to investigate this effect (100, 600, 1100, and 1600 milliseconds). Presumably, at rapid rates of serial digit presentation, the utilization of a mediational strategy would be minimized and/or eliminated. Conversely, at slow rates of serial digit presentation, mediational activity would be more likely to occur in those subjects able to use it productively and effectively. Thus an empirical attempt was made to differentiate primary from secondary memory.

In pursuit of the aforementioned goals the following general research questions were posed: First, is serial digit recall affected by grade? Second, is serial digit recall affected by variable inter-digit delay? Finally, is serial digit recall affected by a Grade X Delay interaction?

METHOD

Subjects

The subjects were fifty-six male school children; fourteen each from grades K (mean age = 5.7 years, s.d. = 4 months), 2 (mean age = 7.8 years, s.d. = 4 months), 4 (mean age = 10.0 years, s.d. = 4 months), and 6 (mean age = 11.9 years, s.d. = 4 months). Further, each subject had an I.Q. score which was within the normal range of intelligence (means and standard deviations for K, 2, 4, and 6, respectively; 103.4, 4.9; 100.5, 6.9; 101.7, 4.7; and 102.2, 6.36). Subjects were obtained from the Gainesville, Florida Public School System.

Apparatus

In order to minimize distraction the digits were presented via audio tape to both ears through headphones. The source tapes were generated on a reel-to-loop dub mechanism at a constant 70 db, and word length was held constant (250 milliseconds plus-or-minus 15 milliseconds). "Scotch" brand reel-to-reel 60 minute (175-1/4-600) tape was used to record the stimulus materials.

The tape was recorded and played to the subjects on a Sony Stereo (model #530) out of the left channel to both ears simultaneously via Koss stereo headphones (model #K-6).

PROCEDURE

Pre-Experimental Treatment Phase. California Tests of Mental Maturity Intelligence Test scores were available for the second, fourth, and sixth grades. Teachers selected those students who did not manifest any evidence of learning difficulties. The Cattell Culture Fair Intelligence Test (Cattell and Cattell, 1960) was administered individually to the Kindergarten children. Kindergarten teachers were asked to refer for testing those children who they felt were of average intellectual ability and who showed no evidence of learning disabilities.

Prior to each treatment presentation a standard pure tone hearing test was administered to each subject to insure against possible transitory hearing loss. The test conditions ranged from 20 to 40 dbs over 125 to 8000 cps. (Beltone Audiometer, model #10-C.)

Treatment Phase. There were four treatment conditions reflecting four variations of inter-digit delay (100, 600, 1100, and 1600 milliseconds). Each subject received a random presentation of each experimental condition. In order to minimize possible practice and/or carryover effects the subjects received three of the treatments 24 hours apart and the last treatment 48 hours after the previous one. Inspection of the data revealed that this random distribution of times did not adversely affect the outcome.

Each subject was tested in a quiet setting. A few minutes was devoted to allow familiarity with the experimenter and the experimental setting. Headphones were then placed on the subject as he sat facing the experimenter. Instructions were given by tape (see Appendix A).

Each treatment condition consisted of nine paired trials of serial digit presentation (see Appendix B), consisting, successively, of from one to nine digits. Five seconds prior to each trial the subject received an orienting beep (70 db, one-second duration) which signified the approach of a trial. A forty-five-second interval elapsed between the onset of each trial and was selected to insure the subject sufficient time for recall.

The ordered recall scores for each subject was the highest trial number in which he correctly recalled all of the numbers presented in correct order up to two consecutive failures on the same trial. All subjects received all nine trials of every condition regardless of where he failed.

RESULTS

Ordered Recall

The digit recall data were subjected to a Grade X Delays Split Plot Factorial analysis of variance (Kirk, 1969) with repeated measures on the Delay factor (Grade: $F = 24.09$, $df = 3/52$, $p < .01$; Delay: $F = 10.04$, $df = 3/156$, $p < .01$; Grade X Delay: $F = 2.05$, $df = 9/156$, $p < .05$).

The analysis of variance indicated that there was a significant difference in the mean number of digits recalled across Grade levels ($p < .01$). *A Posteriori* pairwise comparisons of Grade showed that recall scores for the Kindergarten subjects were significantly lower than those for second ($q = 4.75$, $df = 4/52$, $p < .01$), fourth ($q = 9.23$, $df = 4/52$, $p < .01$), and sixth grade subjects ($q = 10.92$, $df = 4/52$, $p < .01$). Additionally, *A Posteriori* pairwise comparisons revealed that second grade subjects had significantly lower scores than those for fourth ($q = 4.48$, $df = 4/52$, $p < .01$), and sixth grade subjects ($q = 6.17$, $df = 4/52$, $p < .01$). Figure 1 is a graphic representation of the recall scores across grades. It shows that the mean number of digits recalled increased as a function of grade. In the present study this trend began to reach an asymptote between grades four to six.

There was a significant Delay effect ($p < .01$) in the number of digits correctly recalled. *A Posteriori* pairwise comparisons of Delay showed that recall scores in the 100 millisecond condition were

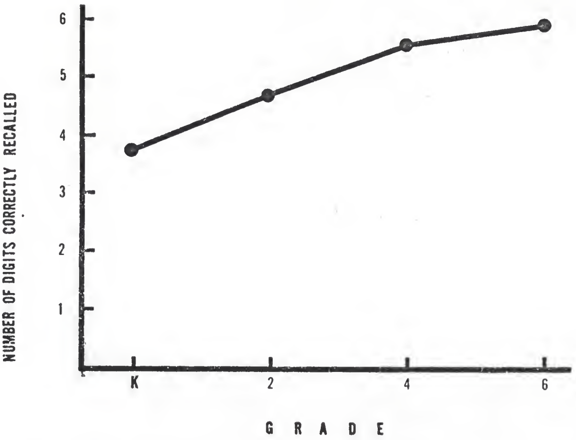

Figure 1. Mean number of ordered digits correctly recalled as a function of grade

significantly better than those in the 600 ($q = 3.22$, $df = 4/156$, $p < .05$), the 1100 ($q = 8.01$, $df = 4/156$, $p < .01$), and the 1600 millisecond condition ($q = 4.02$, $df = 4/156$, $p < .01$). Furthermore, A Posteriori pairwise comparisons of the 1100 to the 1600 millisecond condition revealed that, at the 1600 millisecond condition, the mean number of digits correctly recalled was significantly greater than at the 1100 millisecond condition ($q = 3.95$, $df = 4/156$, $p < .01$). Figure 2 is a graphic representation of the Delay effect on the number of digits correctly recalled. It clearly demonstrates that the best recall scores occurred in the 100 millisecond condition, after which recall performance declined in the 600 to the 1100 millisecond conditions and then significantly improved ($p < .01$) at the 1600 millisecond condition.

There was a significant ($p < .05$) Grade X Delay interaction effect on the mean number of digits correctly recalled. In general, the number of digits correctly recalled increased as a function of Grade across all four treatment conditions. However, this increase across the various treatment conditions was not parallel as indicated by the significant interaction effect. Figure 3 is a graphic representation of the Grade X Delay interaction. Visual inspection reveals overall increasing curves for the 600, 1100, and 1600 millisecond conditions which appear to have reached an asymptote between grades four to six. However, the 100 millisecond condition continued to accelerate between grades four and six. A Posteriori pairwise comparisons of the 100 and 1600 millisecond conditions at the kindergarten and sixth grade level showed that there was a significant difference between the 100 and 1600 millisecond recall scores

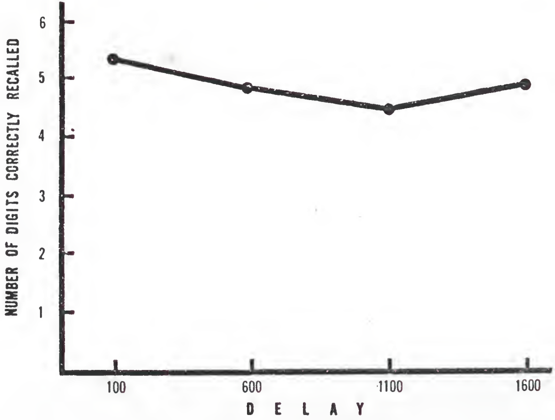

Figure 2. Mean number of ordered digits correctly recalled as a function of delay

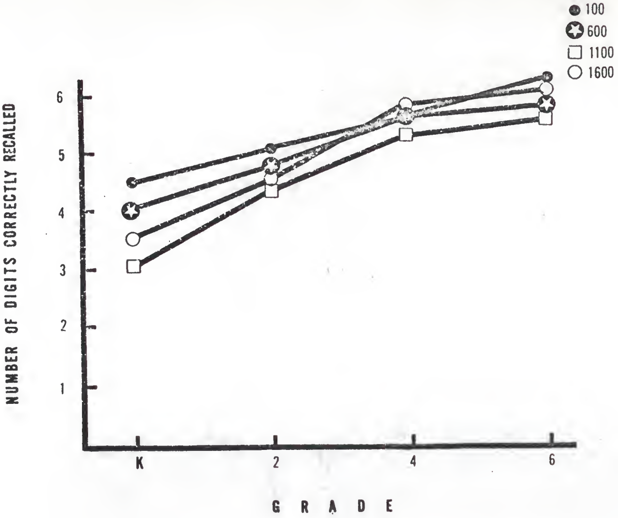

Figure 3. Mean number of ordered digits correctly recalled by grade for each treatment

for the kindergarten subjects ($F = 13.69$, $df = 4/156$, $p < .01$) but not for the sixth grade subjects ($F = 3.27$, $df = 4/156$, $p \geq .01$).

The Grade X Delay interaction was examined from another vantage point in order to look at the changes within Grades over Delay. These data are graphically depicted in Figure 4 which shows the decrease in recall scores from the 100 to the 1100 millisecond conditions followed by the increase in the number of digits recalled from the 1100 to the 1600 millisecond conditions.

Finally, the Omega Square (w^2) statistic indicated that Grade accounted for 39% of the total recall variance, Delay accounted for 4% of the total recall variance, and the Grade X Delay interaction accounted for 1% of the total recall variance. In sum, Grade, Delay, and the Grade X Delay interaction were all significantly related to the mean number of digits correctly recalled and accounted for 44% of the total digit recall variance.

Free Recall

Every subject received every trial of each condition regardless of the point at which he failed. As a result, some additional and interesting data were obtained.

Each subject displayed a recall pattern in which he consistently reported the digits in the order in which they were presented. When he was no longer able to correctly report the digits in sequence he then reported the correct digits, but not in the sequence in which they were presented. After the ordered and then the free recall, errors of omission and commission appeared. Thus, a consistent pattern of recall occurred

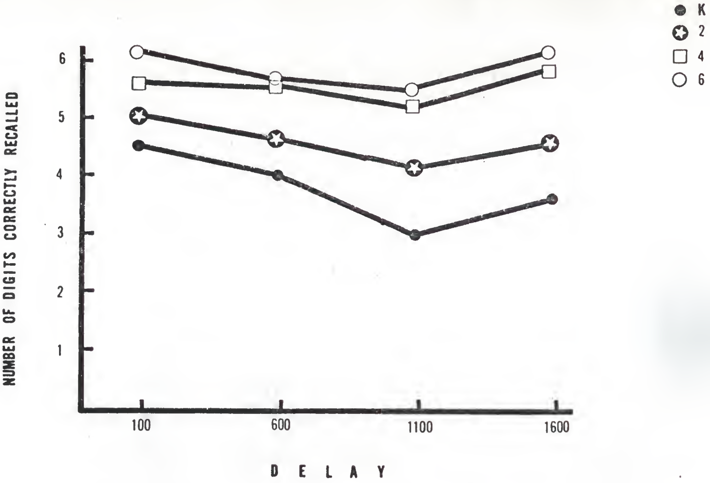

Figure 4. Mean number of ordered digits correctly recalled by treatments for each grade.

going from ordered to free to error although the instructions did not indicate a preferred pattern of recall.

It was of interest to compare the free to the ordered recall. Therefore, every subject was scored for both ordered and free recall as follows: If the subject identified all of the digits in the correct order of presentation the response was scored as a correct recall; if he correctly identified all of the digits, but not the order of presentation, the response was scored as a free recall. Thus, in this study, free recall scores were always at least equal to, or greater than, ordered recall scores.

In order to compare ordered to free recall responses, difference scores were calculated. Thus, the dependent variable for this analysis was a difference score computed by subtracting the ordered from the free recall scores for each subject under each treatment condition.

The difference score data were subjected to a Grade X Delay Split Plot analysis of variance (Kirk, 1969) with repeated measures on the Delay factor (Grade: $F = 2.46$, $df = 3/52$, $p > .10$; Delay: $F = 2.99$, $df = 3/156$, $p < .05$; Grade X Delay interaction: $F = 3.44$, $df = 9/156$, $p < .05$).

There was a significant effect ($p < .05$) attributable to Delay in the free-minus-ordered difference scores. A Posteriori pairwise comparison across Delay indicated that the mean difference scores for the 100 millisecond condition were significantly greater than those for the 600 ($q = 3.59$, $df = 4/156$, $p < .05$), the 1100 ($q = 3.37$, $df = 4/156$, $p < .05$) and the 1600 millisecond conditions ($q = 6.17$, $df = 4/156$, $p < .01$). Additionally, A Posteriori pairwise comparisons also revealed that the 1600 millisecond condition produced significantly lower difference scores than either the 600 ($q = 2.61$, $df = 4/156$, $p < .05$) or the 1100 millisecond conditions ($q = 2.84$, $df = 4/156$, $p < .05$). Figure 5 is a graphic representation of this Delay effect. The graph clearly shows that longer delays resulted in a reduction of the difference scores. The 100 millisecond condition produced the greatest differences while the 1600 millisecond condition produced the smallest.

There was also a significant Grade X Delay interaction effect ($p < .05$). Figure 6 is a graphic representation of these Grade X Delay data. Of particular interest is the difference between the curves for the kindergarten, and the fourth and sixth grade subjects across the various treatment conditions. In general, inspection of Figure 6 reveals that kindergarten children show the least shift in mean difference scores across the four treatment conditions, as well as the lowest average difference scores across treatments. Conversely, the fourth and sixth graders displayed the largest difference scores as well as the greatest degree of change across the four conditions. A Posteriori comparisons revealed that the fourth and sixth grades produced significantly greater differences at the 100 ($F = 38.03$, $df = 3/52$, $p < .01$) and the 1600 millisecond conditions ($F = 11.47$, $df = 3/52$, $p < .05$) than did the kindergarten subjects.

Effects of Grade and Delay on Ordered Serial Position Recall Curves

Traditional primacy-recency effects were most clearly depicted on recall of the eight digit series. Figure 7 shows the serial position curves for the 100 millisecond ordered condition for each grade level.

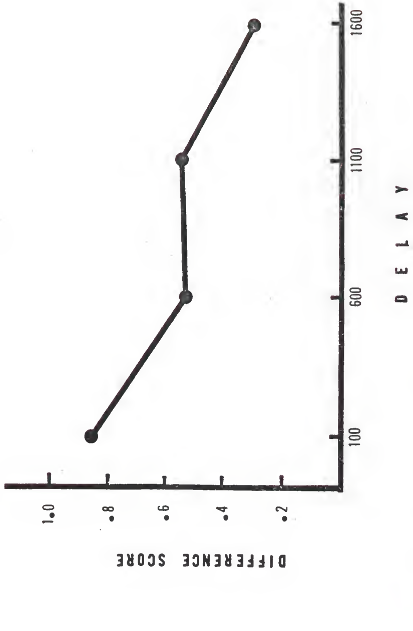

Figure 5. Mean free/ordered differences as a function of delay

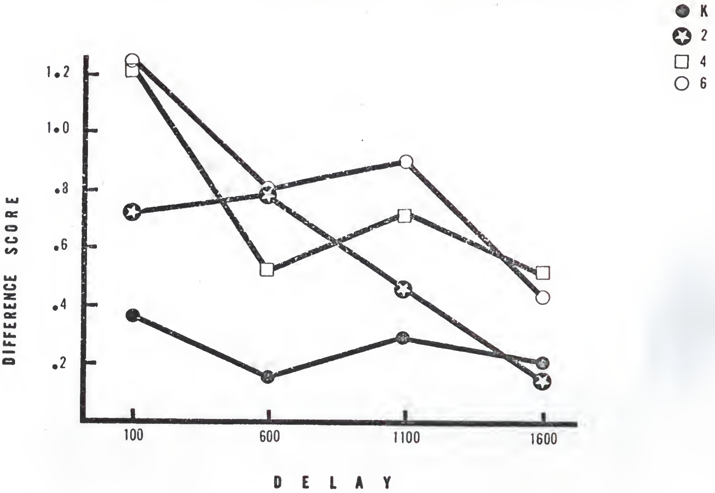

Figure 6. Mean free/ordered differences plotted for each grade across treatments

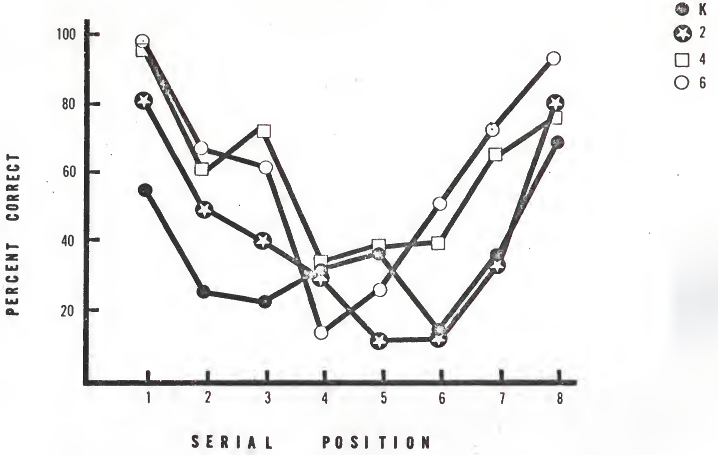

Figure 7. Serial position curve for 8 digits at the 100 millisecond ordered condition for each grade

The primacy and recency effects were not substantially different from each other at this speed of digit presentation for subjects at each grade level. In general, upper grade children were superior to lower grade children in both primacy and recency recall, but the difference was not especially dramatic. However, increased inter-digit delays produced an interesting effect, most clearly depicted in Figure 8, which shows the serial position curves for eight digits at the 1600 millisecond ordered condition for each grade. While recency effects were very similar between grade levels in the 1600 millisecond delay condition, there was a dramatic difference in primacy scores at each grade level. Basically, the kindergarten subjects displayed very poor primacy recall followed by the second graders, while primacy recall in the fourth and sixth graders was very similar to the recency effect for these subjects.

In order to complete the comparison of free to ordered recall the primacy and recency curves were plotted for free recall. Figure 9 shows the serial position curves for eight digits at the 100 millisecond free recall condition. This curve was representative, in terms of its shape, to primacy-recency curves at other Delay and trial conditions.

Visual inspection reveals a rather erratic pattern of recall proficiency, not the classic "u-shaped" serial position curve commonly seen in the ordered recall performance. This discrepancy between ordered and free recall primacy-recency curve shapes was consistent throughout Delay conditions and serial digit lengths.

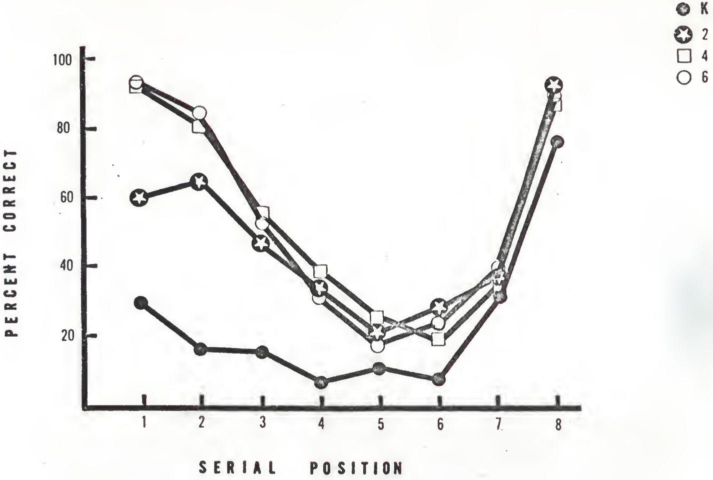

Figure 8. Serial position curve for 8 digits at the 1600 millisecond ordered condition for each grade

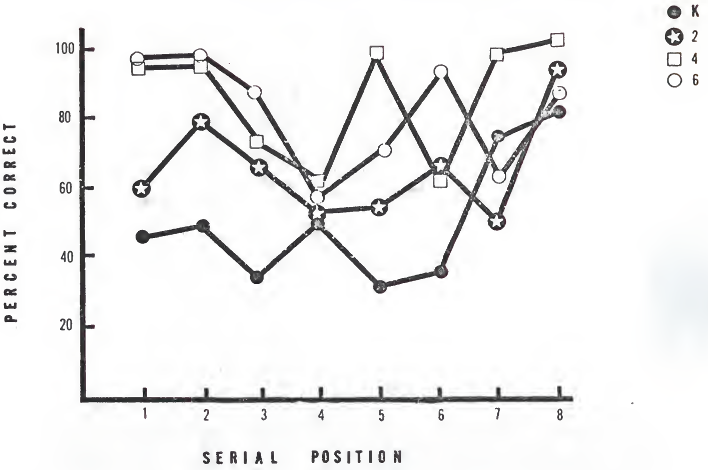

Figure 9. Serial position curve for 8 digits at the 1600 millisecond free condition for each grade

DISCUSSION

Sufficient evidence exists to support the observation that serial digit recall increases with age (Wechsler, 1949). Consistent with Wechsler's data, the developmental curves of correct digit recall in the present study increased linearly until the ages of 10 to 12 years under three of the four treatment conditions. However, they showed no evidence of reduced acceleration under the 100 millisecond condition.

Thus, if a child's age is known it is possible to predict his recall performance with reasonable accuracy. However, it is unclear what variables account for this improvement with age. Physiologically, increased recall may be a function of progressive myelinization which results in increased speed of impulse conduction (Campbell and Spear, 1972). Structurally, improvement may be due to the functional maturity of association areas (Campbell and Spear, 1972), the maturation of limbic system structures as they have been related to learning phenomena (Isaacson et al., 1971), or the maturation of attentional mechanisms (Campbell and Spear, 1972). Experientially, increased recall may be a function of cognitive development as manifested in the increasingly sophisticated use of mediational strategies (Belmont and Butterfield, 1969; Hagen, 1971; Flavell, 1971; Neimarck, Slotman and Ulricht, 1971).

The present study attempted to examine the development of serial digit recall under different inter-digit delay conditions in an effort to acquire information regarding the use of mediational strategies. In general, it was assumed that short inter-digit intervals would interfere with the use of mediational strategies and thereby reduce recall efficiency. Conversely, long inter-digit intervals would presumably be more conducive to the utilization of mediational strategies, and would therefore increase the efficiency of digit recall.

Unfortunately, the ordered recall data analysis offered no support for the notion of superior recall under the longer inter-digit delay conditions. Surprisingly, digit recall was slightly superior under the 100 millisecond inter-digit delay conditions for subjects at all grade levels except the fourth grade where recall differences were the least different across the four conditions. Furthermore, the 100 millisecond curve showed no signs of deceleration. Thus, in terms of the ordered recall data, the present study did not provide support for the mediational strategy hypothesis, if it is assumed that the 100 millisecond inter-digit delay condition is too short for an active strategy to be used. It is probably more reasonable to assume that the superior performance under the 100 millisecond condition was related to central nervous system development as expressed in such concepts as passive exposure memory (Belmont and Butterfield, 1969), electrical memory (Isaacson et al., 1971), or sensory memory (Waugh and Norman, 1965).

Additionally, sheer temporal contiguity of the digits, in the absence of any active cognitive strategy, may have been the factor which accounted for the subjects' better performance under the 100 millisecond condition. It is interesting to note that observation of the subjects revealed no evidence of the sub-vocalized strategies reported in other studies (Belmont and Butterfield, 1969), nor did questioning of the subjects reveal any evidence to suggest that active cognitive strategies were employed to facilitate performance. Therefore, it would be more reasonable to assume that recall, in general, was more a function of non-cognitive factors (e.g., general development of central nervous system structures and/or physiological processes), and that temporal contiguity was the second most important factor accounting for the obtained data (i.e., w^2 for age was 39%, while that for inter-digit delay was 4%).

While there was no evidence that cognitive strategies were employed by subjects under the longer inter-digit delay conditions, it is possible that performance differences in favor of greater recall under the longer delay conditions might only emerge in a delayed recall paradigm. That is, the slight superiority of recall under the 100 millisecond condition may be idiosyncratic to an immediate recall paradigm, and that better recall under longer inter-digit delay conditions might occur only when there is a time delay before recall is given. In essence, rapid input of sensory information without much opportunity for active cognitive manipulation or evaluation might be rapidly and reasonably accurately recalled, but may dissipate quickly as a memory trace. Conversely, while more slowly presented information may result in the same or nearly the same immediate recall as that presented rapidly, slowly presented material may be subject to longer periods of storage, assuming that some conscious or unconscious process is occurring which might facilitate its retention.

While the ordered recall data plotted across grade levels did not reveal any evidence to support an hypothesis of superior recall for longer inter-digit intervals, there was some interesting information revealed regarding the delay conditions when the data for each grade were plotted across the delay intervals. Although the grade curves plotted across the delay conditions still reveal superiority in recall for the 100 millisecond delay, there is clear improvement in performance which is most evident between the 1100 and 1600 millisecond delays. This acceleration might reasonably continue with longer delay intervals and conceivably reach a point at which performance would surpass that of the 100 millisecond delay. Such a finding would clearly provide support for a mediational strategy hypothesis, especially if some independent evidence could be additionally obtained, from subject observation or verbal report, that subjects engaged in some active strategy.

Other circumstantial evidence suggestive of the appearance of mediational strategies emerged from the analysis of the serial position data under the 100 and 1600 millisecond conditions. Both conditions depict the expected or typically obtained superiority of digit recall for the initial and final digits of a series. Additionally, there was increased superiority of digit recall with increased age. However, there was a striking difference between the two treatment conditions as indicated by the marked inferiority of primacy recall under the 1600 millisecond condition for the kindergarten subjects, and to a somewhat lesser extent, for that of the second graders. Although no evidence was obtained to suggest that mediational strategies were employed, it has been inferred that such age-related differences in primacy-recency data reflect the utilization of mediational strategies which somehow enable the subject to retain incoming sensory information for longer periods of time (Ellis, 1969; Belmont and Butterfield, 1969).

Since there is evidence to suggest that five-and six-year old children either do not have mediational strategies (Flavell, 1970; Goulet, 1968; Rossi, 1964; Daeler et al., 1969; Cole, Frankel and Sharp, 1971; Corsini et al., 1968; Moely et al., 1969), or at best use them ineffectively (Kendler, 1963; Luria, 1961; Reese, 1962), it might be reasoned that the poor performance of kindergarten children under the 1600 millisecond condition reflected an inability to retain primacy information because they were unable to employ some mediational device which would facilitate longer retention. Conversely, primacy recall for kindergarten children may have been easier under the 100 millisecond condition because of the shorter temporal interval between primacy elements and recall. More specifically, Belmont and Butterfield (1969) hypothesized that recency effects reflect primary memory and primacy effects reflect secondary memory. With the primacy effect it is felt that the passage of time after the presentation of the initial portion of a serial list provides time for the potential implementation of a mediational strategy and subsequent transfer of information into secondary memory. However, such a phenomenon might occur only when the total temporal interval is relatively long, as in the 1600 millisecond condition.

While the Belmont and Butterfield (1969) speculation makes intuitive sense, they have not yet provided any empirical evidence to support the notion that mediational strategies are employed in serial digit paradigms identical to the one employed in the present study. In fact, they have found that fixed time intervals often interfere with the utilization of mediational strategies, especially in older subjects with well-developed idiosyncratic strategies. Additionally, as previously mentioned, there was no evidence from the present study to suggest that subjects employed mediational strategies. Thus, the primacy-recency data might be explained more simply in terms of central nervous system maturity.

Finally, an interesting finding occurred with respect to recall. Even though the subjects were not told to recall the digits in the precise order in which they were presented they nevertheless did. When the subjects were unable to recall the digits in the order of presentation, they consistently shifted to free recall. After they could no longer recall the digits either in order, or in and of themselves, then errors of omission and commission occurred. In general, the data show a clear trend for greater free recall at the fourth and sixth grade levels under the 100 millisecond condition, and to a lesser extent, under the 1600 millisecond condition. The data raise a number of interesting questions and/or inconsistencies with respect to interpretation. Basically, all subjects showed a preference for ordered recall until they reached what appeared to be their recall capacity. This finding would suggest that ordered recall was the easiest or most parsimonious way to recall the digits. The older children, however were able to recall correctly additional digits after they were unable to recall them in correct serial order, implying that retention of order becomes increasingly difficult as the serial digit length increases. Conversely, younger children showed almost no free recall; that is, once they reached their capacity for ordered recall, they began to make errors of omission and commission. However, inasmuch as free recall surpasses ordered, it could be argued that ordered recall is not always the easiest way to recall information. In essence, the data seem to suggest an interaction in which ordered recall is the most parsimonious way of handling information up to some level of difficulty, but that it is not effective beyond that point.

Alternately, it may be that younger children interpret their world in a more concrete manner than older children (Flavell, 1963) and consequently cannot separate out the components of complex stimuli. Thus, for them to report the digits correctly, they must do so in the order in which they perceived them. Conversely, the older children are not so concrete and may be better able to separate the various stimuli components. Consequently they were able to report additional digits without regard to the perceived order.

Finally, while the free recall scores for the older children significantly decelerated from the 1100 to the 1600 millisecond condition, the ordered recall scores significantly accelerated. While there is little direct evidence that mediational strategies were invoked at this inter-digit interval, there is some indirect evidence that they may have been. A possible explanation for the continued decrease of free recall scores can be offered if indeed mediational strategies were operating at this delay condition. That is, the mediational rule used may have filled up some of the memory space previously allocated to free recall. If the mediational rule did in fact fill up some free recall space then it follows that there would be a significant reduction in free recall at the same time that ordered recall was increasing. This model is similar to the psycholinguistic model of sentence processing (Savin and Perchonock, 1965).

Summary

Ordered serial digit recall in males increases significantly with age following typical maturation patterns and begins to reach an asymptote between 10 and 12 years of age.

Variable inter-digit delay was significantly related to the mean number of digits correctly recalled. However, there was no direct evidence, either in the form of sub-vocalizations or subject awareness, of the implementation of mediational strategies. There was some indication that extension of the delay conditions using the present paradigm might provide supplemental evidence, which, in conjunction with more direct evidence, could support the hypothesis of mediational strategies in serial digits paradigms of this type.

APPENDIX A

TAPED INSTRUCTIONS GIVEN TO SUBJECTS

"I want to see how many numbers you can remember. You will hear a beep. Then you will hear a number being said. I want you to listen very carefully. When the voice stops talking tell me all of the numbers that you heard. If you do not understand what we are going to do tell me to explain it again to you."

APPENDIX B

DIGIT PRESENTATION FOR THE FOUR TREATMENT CONDITIONS

TREATMENT ONE

Trial 1 :	4	6
Trial 2 :	1 3	8 1
Trial 3 :	2 7 5	9 5 2
Trial 4 :	3 9 6 2	4 7 3 1
Trial 5 :	4 7 1 5 3	3 5 9 6 4
Trial 6 :	5 4 6 3 2 7	2 8 7 1 9 3
Trial 7 :	1 8 9 7 4 6 2	7 4 8 5 1 6 3
Trial 8 :	9 2 7 4 6 8 1 3	8 1 7 4 3 6 2 5
Trial 9 :	3 5 9 6 4 2 8 7 1	3 6 2 7 4 1 5 9 8

TREATMENT TWO

Trial 1 :	3	6
Trial 2 :	6 1	3 1
Trial 3 :	2 1 4	1 4 6
Trial 4 :	3 5 8 6	6 1 8 5
Trial 5 :	9 2 6 5 3	2 5 6 3 7
Trial 6 :	4 3 5 2 7 1	3 5 6 2 9 8
Trial 7 :	5 9 8 6 7 3 1	1 3 7 6 8 9 2
Trial 8 :	8 2 6 5 9 3 7 4	4 8 6 5 1 9 3 7
Trial 9 :	7 3 2 5 6 1 4 9 8	2 5 3 6 7 4 9 1 8

TREATMENT THREE

Trial 1 :	8	9
Trial 2 :	1 9	8 4
Trial 3 :	4 7 6	1 6 5
Trial 4 :	3 5 2 7	6 4 7 9
Trial 5 :	3 9 1 5 6	5 3 2 9 8
Trial 6 :	8 4 2 9 3 1	2 1 4 7 5 9
Trial 7 :	9 8 6 7 3 1 5	1 4 2 6 5 7 3
Trial 8 :	6 4 1 3 7 5 9 8	8 6 9 5 4 7 1 3
Trial 9 :	5 7 4 6 8 9 3 1 2	4 6 5 7 1 9 2 3 8

TREATMENT FOUR

Trial 1 : 7	1
Trial 2 : 5 8	7 5
Trial 3 : 4 5 3	3 9 6
Trial 4 : 6 9 7 4	4 7 5 8
Trial 5 : 1 3 2 7 5	2 6 3 8 4
Trial 6 : 2 7 3 6 9 4	2 8 5 9 3 6
Trial 7 : 4 6 7 5 1 9 2	8 4 9 2 7 3 1
Trial 8 : 3 7 5 1 4 2 6 8	1 8 9 3 5 2 4 6
Trial 9 : 2 4 1 8 5 6 9 7 3	1 8 7 9 3 2 4 6 5

REFERENCES

Appel, L.F., Cooper, R.G., McCarrell, N., Sims-Knight, J., Yussen, S.R., and Flavell, J.H. The developmental acquisition of the distinction between perceiving and memorizing. Child Development, in press.

Barbizet, J. Human Memory and its Pathology. San Francisco: W.H. Freeman & Co., 1970.

Baumeister, A.A. Problems in comparative studies of mental retardates and normals. American Journal of Mental Deficiency, 1967, 71, 869-875.

Belmont, J.M., and Butterfield, E.C. The relation of short-term memory to development and intelligence. Advances in Child Development and Behavior, 1969, 4, 29-47.

Broadbent, D.E., Perception and Communication. London: Pergamon Press, 1958.

Campbell, B.A., and Spear, N.E. Ontogeny of memory. Psychological Review, 1972, 79(3), 215-237.

Carroll, J.B. Learning from verbal discourse in educational media: A review of the literature. Educational Testing Service, Princeton, New Jersey, Oct., 1971.

Cattell, R.B., and Cattell, A.K.S. Handbook for the Individual or Group Culture Fair Intelligence Test (A Measure of "g"): Scale One. Institute for Personality and Ability Testing, Champaign, Illinois, 1960.

Cattell, R.B., and Cattell, A.K.S. Handbook for the Individual or Group Culture Fair Intelligence Test (A Measure for "g"): Scale Two. Institute for Personality and Ability Testing, Champaign, Illinois, 1960.

Cole, M., Frankel, F., and Sharp, D. Development of free recall learning in children. Developmental Psychology, 1971, 4(2), 109-123.

Corsini, D.A., Pick, A.D., and Flavell, J.H. Production of nonverbal mediators in young children. Child Development, 1968, 39, 53-58.

Daehler, M.W., Horowitz, A.B., Wynns, F.C., and Flavell, J.H. Verbal and nonverbal rehearsal in children's recall. Child Development, 1969, 40, 443-452.

Ellis, N.R. The stimulus trace and behavioral inadequacy. In: N.R. Ellis (Ed.), Handbook of Mental Deficiency. New York: McGraw-Hill, 1963, pp. 134-158.

Ellis, N.R. Evidence for two storage processes in short-term memory. Journal of Experimental Psychology, 1969, 80, 390-391.

Fergenhaum, E.A., and Simon, H.A. A theory of the serial position effect. British Journal of Psychology, 1962, 53(8), 307-320.

Flavell, J.H. The Developmental Psychology of Jean Piaget. New York: Van Nostrand and Co., 1963.

Flavell, J.H. Developmental studies of mediated memory. Advances in Child Development and Behavior, 1970, 5, 182-209.

Flavell, J.H. First discussants comments: What is memory development the development of? Human Development, 1971, 14, 272-278.

Flavell, J.H., Beach, D.H., and Chinsky, J.M. Spontaneous verbal rehearsal in a memory task as a function of age. Child Development, 1966, 37, 283-299.

Flavell, J.H., Friedrichs, A.G., and Hoyt, J.D. Developmental changes in the memorization process. Cognitive Psychology, 1970, 1, 324-340.

Glucksberg, S., and Danks, J.H. Grammatical structure and recall: A function of the space in immediate memory or of recall delay. Perceptual Psychophysics, 1969, 6, 113-117.

Goulet, L.R. Verbal learning in children: Implications for developmental research. Psychological Bulletin, 1968, 69, 359-376.

Hagen, J.W., and Kingsler, P.R. Labelling effects in short-term memory. Child Development, 1968, 39, 113-121.

Hagen, J.W. Some thoughts on how children learn to remember. Human Development, 1971, 14, 262-271.

Heilman, K. Personal Communication, 1972.

Isaacson, R.L., Douglas, R.J., Lubar, J.F., and Schmaltz, L.W. A Primer of Physiological Psychology. New York: Harper and Row, 1971.

Keeney, T.J., Cannizzo, S.R., and Flavell, J.H. Spontaneous and induced verbal rehearsal in a recall task. Child Development, 1967, 38, 953-966.

Kelly, G.A. The Psychology of Personal Constructs, Vol. 1. New York: W.W. Norton and Co., 1955.

Kendler, T.S. Development of mediating responses in children. In: J.C. Wright and J. Kagan (Eds.), Basic Cognitive Processes in Children. Monographs of the Society for Research in Child Development, Chicago, 1963, 28(2), 33-52.

Kirk, R.E. Experimental Design: Procedures for the Behavioral Scientist. Belmont, California: Brooks-Cole Publishing Co., 1969.

Luria, A.R. The genesis of voluntary movements. In: N. O'Connor (Ed.), Recent Soviet Psychology. New York: Macmillan (Pergamon), 1961, pp. 165-185.

Matthews, W.A. Transformational complexity and short-term recall. Lang. Speech, 1968, 11, 120-128.

McCall, R.B. Attention in the infant: Avenue to the study of cognitive development. In: D.N. Walcher and D.L. Peters (Eds.), The Development of Self-Regulatory Mechanisms. New York: Academic Press, 1971.

McCrary, J.W., and Hunter, W.S. Serial position issues in verbal learning. Science, 1953, 17(8), 131-134.

McGaugh, J.L. Memory storage processes. In: K.H. Pribram and D.E. Broadbent (Eds.), The Biology of Memory. New York: Academic Press, 1970, pp. 51-62.

McMahon, L.E. Grammatical analysis as part of understanding a sentence. Doctoral Dissertation, Harvard University, 1963.

Melton, A.W. Short- and long-term postperceptual memory: Dichotomy or continuum. In: K.H. Pribram and D.E. Broadbent (Eds.), The Biology of Memory. New York: Academic Press, 1970, pp. 3-6.

Miller, G.A. The magical number seven plus or minus two: Some limits on our capacity for processing information. Psychological Review, 1956, 63, 81-97.

Milner, B. Memory and medial temporal regions of the brain. In: K.H. Pribram and D.E. Broadbent (Eds.), The Biology of Memory. New York: Academic Press, 1970, pp. 29-49.

Moely, B.E., Olson, F.A., Halwes, T.G., and Flavell, J.H. Production deficiencies in young childrens' clustered recall. Developmental Psychology, 1969, 1, 26-34.

Murdock, B.B. The criterion problem in short-term memory. Journal of Experimental Psychology, 1966, 72, 317-324.

Neimarck, E., Slotman, N.S., and Ulricht, T. The development of memorization strategies. Developmental Psychology, 1971, 5, 427-432.

Nevelsky, P.B. Comparative investigation of the short- and long-term memory span. In: K.H. Pribram and D.E. Broadbent (Eds.), Biology of Memory. New York: Academic Press, 1970, pp. 21-28.

Norman, D.A. Acquisition and retention in short-term memory. Journal of Experimental Psychology, 1966, 72, 369-381.

Norman, D.A. Memory and Attention. New York: John Wiley and Sons, 1969.

O'Connor, N., and Hermelin, B. Input restriction and immediate memory decay in normal and sub-normal children. Quarterly Journal of Experimental Psychology, 1965, 17, 323-328.

Reese, H.W. Verbal mediation as a function of age level. Psychological Bulletin, 1962, 59, 502-509.

Rossi, E. Development of classificatory behavior. Child Development, 1964, 35, 137-142.

Savin, H.G., and Perchonock, E. Grammatical structure and the immediate recall of English sentences. Journal of Verbal Learning and Verbal Behavior, 1965, 4, 348-353.

Smirnov, A.A., and Zinchenko, P.I. Problems in the psychology of memory. In: M. Cole and I. Maltzman (Eds.), A Handbook of Contemporary Soviet Psychology. New York: Basic Books, 1969, pp. 452-502.

Tulving, E., and Patkav, J.E. Concurrent effects of contextual constraint and word frequency on immediate recall and learning of verbal material. Canadian Journal of Psychology, 1962, 16, 83-95.

Tulving, E. Short- and long-term memory: Different retrieval mechanisms. In: K.H. Pribram and D.E. Broadbent (Eds.), The Biology of Memory. New York: Academic Press, 1970, pp. 7-10.

Von Bekesy, G., and Rosenblith, W.A. The mechanical properties of the ear. In: S.S. Stevens (Ed.), Handbook of Experimental Psychology. New York: John Wiley and Sons, 1951.

Ward, J.E., and Jennings, E. Introduction to Linear Models. New York: Prentice-Hall, Inc., 1973.

Waugh, N.C. Primary and secondary memory in short-term retention. In: K.H. Pribram and D.E. Broadbent (Eds.), The Biology of Memory. New York: Academic Press, 1970, pp. 63-68.

Waugh, N.C., and Norman, D.A. Primary memory. Psychological Review, 1965, 72, 89-104.

Wechsler, D. The Wechsler Intelligence Scales for Children. New York: Psychological Corporation, 1949.

BIOGRAPHICAL SKETCH

Gary Steven Sarver was born November 20, 1946, at Boston, Massachusetts. In June, 1964, he was graduated from Hull High School. In September, 1964 he entered Boston University from which he was graduated with Distinction in Psychology in May, 1969.

In September, 1969, he began his graduate studies at the University of Florida. He received his master's degree in Psychology in December, 1970. From that time until the present, he has been pursuing his studies towards the degree of Doctor of Philosophy in Psychology.

He has been the recipient of University of Florida Graduate School Fellowships and United States Public Health Service Fellowships. He is a member of Psi Chi.

He is married to the former Ann Howland and they have one daughter, Andrea.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Paul Satz, Chairman
Professor of Clinical Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Wiley C. Rasbury

Wiley, C. Rasbury, Co-Chairman
Assistant Professor of Clinical Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Franz R. Epting
Associate Professor of Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Robert L. Isaacson

Robert L. Isaacson
Professor of Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Frederick A. King

Frederick A. King
Professor and Chairman of Neuroscience

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Jacquelin R. Goldman

Jacquelin R. Goldman
Associate Professor of Clinical
Psychology

This dissertation was submitted to the Department of Clinical Psychology in the College of Arts and Sciences and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

August, 1973

Dean, Graduate School